Terrain Visualization Systems:
Rapid Path to Terrain Understanding

By Mr. Ken Bergman

In the mid-1990s, an Army warrant officer in Korea flew his helicopter north of the demilitarized zone and was shot down. He flew north of the border because he was unfamiliar with the terrain, and he became lost. Joint Task Force –Korea responded by purchasing a mission-rehearsal system called Tactical Operational Scene (TOPSCENE™), a software package that used elevation data with imagery draped over it to provide a three-dimensional (3-D) terrain fly-through, with annotations and labels on key terrain features. The software facilitated night flying because it showed scenes as they would appear using night-vision goggles. The system provided Army helicopter pilots the technology to rehearse missions in Korea many times before ever getting into the cockpit. The Army paid about half-a-million dollars for this high-end TOPSCENE capability, which was supported by a refrigerator-sized workstation. Databases had to be built and maintained by contractors. Although terrain warrant officers could update the databases, this required nonstandard training, and rotation of trained personnel made in-house database generation a challenge. However, the capabilities gained by having this system at Joint Task Force–Korea were extremely useful.

The cost of computers has decreased significantly, and many high-end Unix®-based workstations have been replaced by Windows®-based personal computers (PCs). Today's high-end laptop can easily compare with yesterday's refrigerator-sized workstation in terms of processing capability and speed. Software has rapidly evolved to leverage the new, powerful PCs. There are now literally hundreds of terrain visualization systems that use imagery draped over elevation data to provide 3-D terrain fly-through capabilities.

Terrain Visualization Systems Capabilities

Terrain understanding is a key aspect of warfare. Thousands of years ago, Sun Tzu said that knowing the terrain is a significant advantage on the battlefield. This axiom has not changed. Tactical decision aids built by the Digital Topographic Support System (DTSS) are very useful tools to achieve terrain understanding; for example, the modified combined-obstacle overlay is a tool that is familiar to all topographic engineers. Tactical decision aids are typically used in a two-dimensional (2-D) presentation, either digitally or as hard-copy products. Terrain visualization systems, on the other hand, provide a bird's-eye view of the terrain, to give the user another way to achieve terrain understanding.

Terrain visualization systems use elevation data to provide a basic understanding of the lay of the land (such as hills, valleys, plains, and escarpments). More detailed elevation data provides a better terrain understanding, but it also requires higher data storage and processing capabilities. Imagery or digitized raster maps are draped over the elevation data to display terrain features. As with elevation data, more detailed imagery provides better terrain understanding, but this comes with a data storage and processing cost.

Many terrain visualization systems have additional capabilities:

- Display radar domes and surface-to-air missile threat domes.
- Drape vector (feature) terrain data over elevation data and imagery.
- Add landmarks and signposts for improved orientation.
- Page in more detailed images or maps as you fly closer to the ground.
- Extrude (stand up) buildings to show detailed urban terrain data.
- Render the scene to look like a night-vision or infrared scene.
- Export stand-alone files to any PC for 3-D fly-through capability.
- Interface with battle command systems.

The last two points listed here merit some elaboration, since they are key aspects in the utility of terrain visualization systems.

Export Stand-Alone Files to Any PC

This aspect refers to the recent phenomenon of high-end terrain visualization systems being able to export a file that can run without any software license support. Figure 1, page 34, shows five leading terrain visualization systems that are being used in the field. DTSS Imagizer, TerraExplorer®, and TerraVista® are systems that are capable of exporting stand-alone files to "any PC" (for example, a mainstream Pentium® computer purchased in the last couple of years). The process of building and using terrain visualization data in Figure 1 starts with *source data* (elevation, feature, and urban data and imagery), *data preparation* (processing the data to provide a smooth fly-through), *viewer* (type of file or software used to display the data), and *data interchange* (data

interoperability from the system to other systems). The capability to export stand-alone terrain visualization files makes it possible to provide unlimited copies of compact disks (CDs) or digital video disks (DVDs) to soldiers, who can load the files on their laptops at no cost. This is a huge technology breakthrough that the Army needs to leverage more effectively.

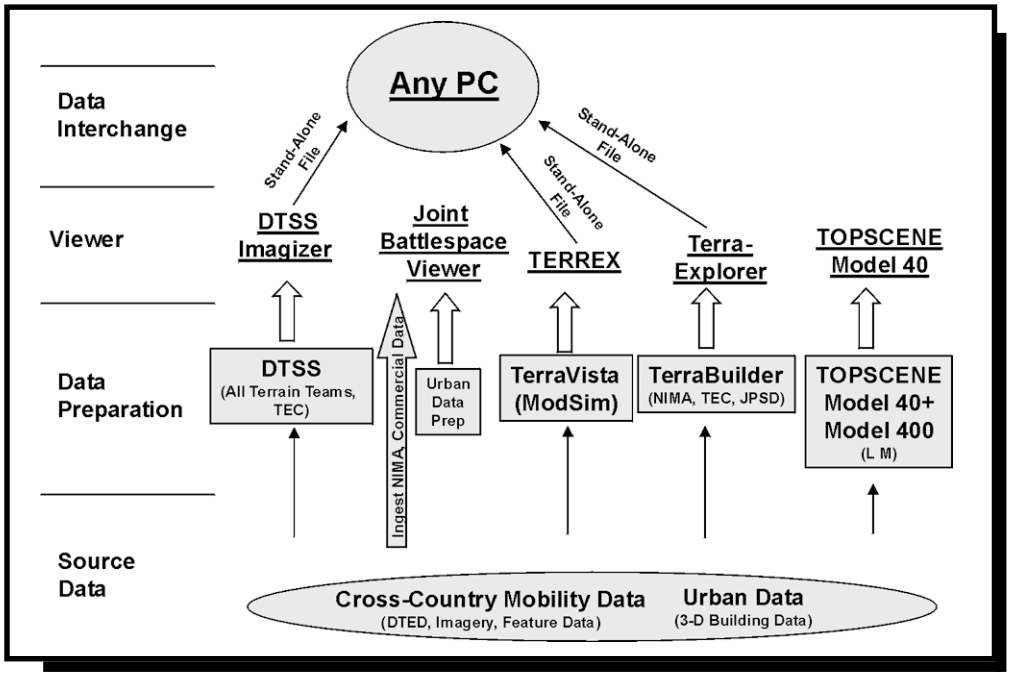

Figure 1. Export Stand-Alone File to Any PC

Interface With Battle Command Systems

Interoperability with battle command systems is another key capability for terrain visualization systems. The acquisition community has developed the Army Battle Command System (ABCS) to achieve command and control in the field. Windows-based systems in the ABCS can use stand-alone 3-D fly-through files (see Figure 2). This figure also shows that products from DTSS can be exported to ABCS workstations using the DTSS overlay provider.

The ABCS is being fielded to numerous units, but fiscal limitations have precluded fielding to all units. Some field units have obtained systems on their own to achieve battle command functionality. Command and control personal computer (C2PC) is a popular government off-the-shelf (GOTS) battle command software package being used by the Army. It uses the media gateway controller (MGC) or "magic" file to display overlays (such as fire support control measures). The Advanced Deep Operations Command and Control System (ADOCS), another popular GOTS battle command system (see Figure 3), can be used to ingest shape files from the DTSS and export MGC files to C2PC. A new software patch in the DTSS enables direct export of MGC files from DTSS to C2PC.

Terrain Visualization Categories

Terrain visualization data can be categorized into two types:

Cross-Country Mobility Data

This terrain visualization data is derived by draping imagery or digitized maps over elevation data. There is some level of elevation data and imagery available over the entire planet, and it is possible to provide some rudimentary level of terrain understanding anywhere in the world.

Urban Data

Urban data is built by extruding buildings, based on an estimation of building heights from image shadows, blueprint

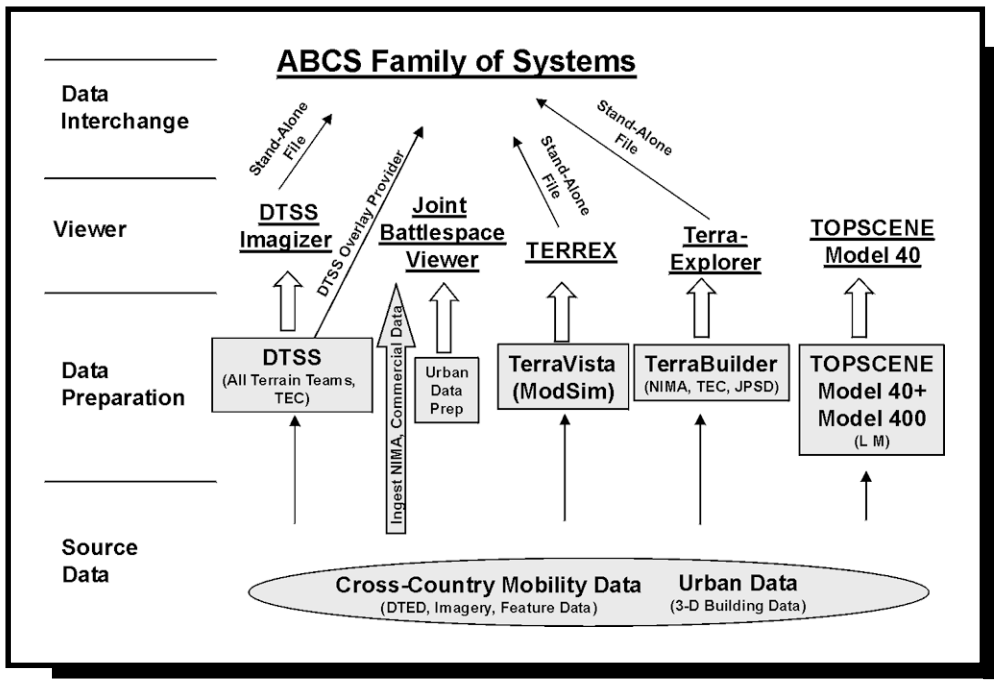

Figure 2. ABCS Terrain Visualization Data Flow

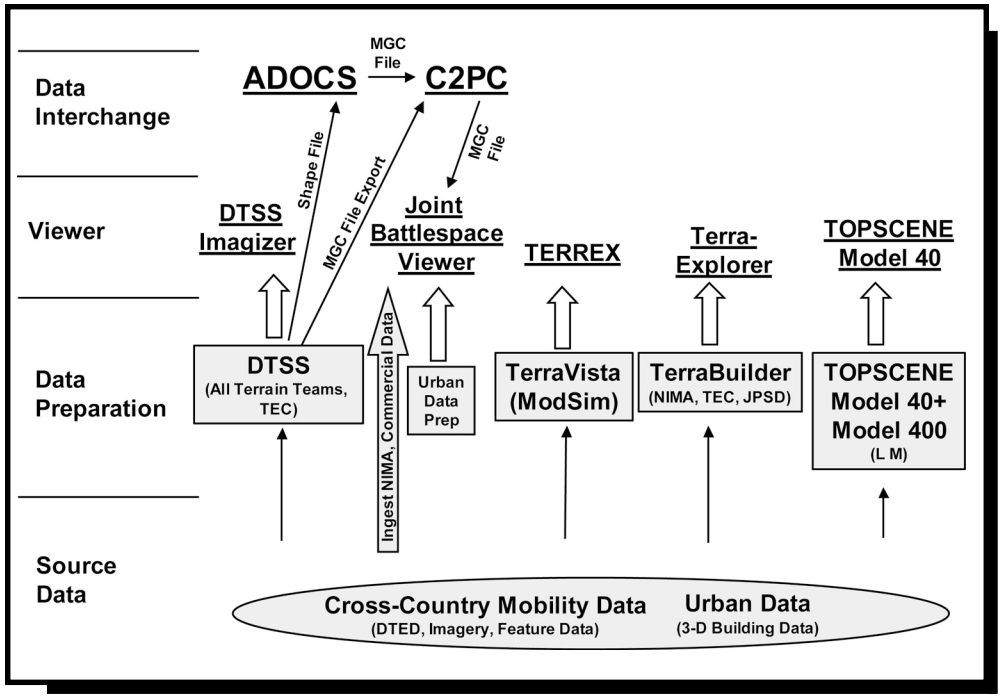

Figure 3. C2PC Terrain Visualization Data Flow

data, or stereo photogrammetry. These are all slow, labor-intensive processes. The only other way to get accurate urban data is to fly a light-detection and ranging sensor over the city to obtain detailed elevation data (1 meter post spacing). Although it is presently not possible to collect urban data using active sensors over denied areas, programs are underway to achieve this capability using unmanned aerial vehicles.

Low-End Software Packages

There are many low-end terrain visualization systems that are free. These systems provide a basic capability to build a 3-D terrain fly-through, but without the impressive visualization capabilities of more powerful high-end systems. TerraBase software, which is trained at the U.S. Army Engineer School at Fort Leonard Wood, Missouri, provides a basic 3-D terrain visualization capability. This GOTS software can be downloaded from the Engineer School Web page (*http://www.wood.army.mil/tvc/DefaultPageContents/MicroDEM_TBII.htm*) for free. TerraBase also provides a variety of other basic geospatial functions. FalconView™ is another free GOTS package that is popular with many users in the field; it is often used in conjunction with C2PC.

High-End Software Packages

More powerful software packages incorporate advanced aspects of terrain visualization. The following systems are currently being used by Army units in the field:

DTSS Imagizer

DTSS software now has the capability to generate the Earth Resources Data Analysis System (ERDAS®) Imagizer file, which can be exported to laptops and PCs as a stand-alone capability. Once the Imagizer 3-D fly-through has been generated on DTSS, it can be disseminated to as many users as needed—for free. Additional tools will be available on the Imagizer file, to include terrain analysis tools, simultaneous 2-D and 3-D displays of detailed data, and the ability to add (ingest) more products. Imagizer will use the Virtual World file generated for the DTSS Virtual Geographic Information System (VGIS®), so terrain analysts are already trained to build data sets. Most PCs can run the Imagizer stand-alone file, but at least a 36-megabyte graphics card is recommended. The DTSS is designed to be compatible with systems in the ABCS architecture. Marine Corps teams are also likely to have this software in the near future, since the DTSS and the Marine Corps topographic production capability have the same basic software architecture.

Joint Battlespace Viewer (JBV)

This free GOTS software, developed by the Navy, requires a PC with a 128-megabyte graphics card. It is capable of using multiple resolutions of imagery and digital raster maps. As the user flies closer to the earth, higher-resolution imagery or map products are displayed automatically. The JBV was designed to have good interoperability with C2PC. Army users who need to achieve data interchange with C2PC have shown a high level of interest in the JBV, which can only use Digital Terrain Elevation Data (DTED) Level 1.

TerraVista®

This system is typically associated with modeling and simulation; however, it is relevant to terrain visualization in that it can be used to build detailed urban terrain data for export as a stand-alone file and also for export as source data for other terrain visualization systems. This is the type of data interchange capability that is needed in a world where different systems are being purchased by field units.

TerraExplorer

This system is used to build large terrain databases that can be displayed on most modern PCs. It can display hundreds of miles of data at varying levels of imagery and elevation resolution, with a "seamless" fly-through. It is very simple to install and use. A key benefit of TerraExplorer is that it can be exported to as many users as necessary, limited only by the file size or the number of CD or DVD copiers available. Another

aspect that is unique to this system is its capability to support Web-streaming video. This means that the 3-D terrain fly-through can be achieved remotely using a Web browser. The National Imagery and Mapping Agency, the Engineer Research and Development Center-Topographic Engineering Center (ERDC-TEC), and the U.S. Army Joint Precision Strike Demonstration Program Office are using this system to provide terrain visualization capabilities to a wide variety of users.

TOPSCENE

As mentioned at the beginning of this article, TOPSCENE has been used for many years by Army units to achieve high-end terrain visualization capabilities. Costs can be relatively low ($1,000 - $5,000 for each viewer software license) or very high (hundreds of thousands of dollars for the top-level data generation hardware and software). Lockheed Martin Corporation builds the database in a company-proprietary format. Soldiers in the field can update and modify the data by purchasing a midlevel capability to edit the data sets. System capabilities include the infrared and night-vision rendering of a scene and data interchange in a number of formats. The Lockheed Martin data sets built under contract to other Department of Defense users can be obtained for use on TOPSCENE-licensed workstations.

Data Interchange

There is a need for data interchange among the various terrain visualization systems that various units have purchased. The costs associated with building and processing a terrain visualization database can be very high. This is particularly true for generation of detailed 3-D features (such as urban buildings). Contractors and government agencies that build terrain visualization data would serve the needs of the Army best if their data could be used by more of the systems in the field. Limited resources for the production of this data could be conserved by data reuse. If a unit built a terrain database over its immediate area, then adjacent units and higher headquarters could use the same data even if they had different terrain visualization systems.

One of the goals for the Objective Force is to have battle command, modeling and simulation, and mission planning and rehearsal systems—all using the same data. The best way to achieve this is to begin using interchangeable data formats that are commonly accepted. OpenFlight® is one example of a terrain data format for 3-D terrain data interchange in the modeling and simulation community. OpenFlight files can be exported from TerraVista and TOPSCENE. Another interchange format that the modeling and simulation community uses is Synthetic Environment Data Representation and Interchange Specification (SEDRIS™), which contains more detailed terrain information than OpenFlight. TerraVista and TOPSCENE can import and export SEDRIS files. Other commercial standard formats are used to represent imagery, elevation, and feature data. DTSS, TerraVista, and TOPSCENE can import and export data in commercial formats. TerraExplorer and JBV can ingest commercial-format terrain data. The use of common terrain data formats must be increased to achieve data interchange for terrain visualization systems.

Nonstandard System Considerations

When field units purchase nonstandard systems, they enhance their capabilities immediately. However, at least one soldier must start performing tasks that were not established by U.S. Army Training and Doctrine Command (TRADOC) schools through the requirements process. Training and maintenance of the system is a task set that is added as a collateral duty, or the new tasks take the place of tasks that the soldier was performing before. A couple of systems added to the unit can improve operations, but the addition of *many* nonstandard systems can become a problem for individual units and for the Army in terms of training and interoperability and achieving common tactics, techniques, and procedures.

The Army's doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) must be adjusted to keep units compatible and interoperable. The TRADOC Program Integration Office for Terrain Data (TPIO-TD) at Fort Leonard Wood, Missouri, is conducting an assessment of terrain visualization systems in conjunction with the ERDC-TEC, the Engineer School, and the TRADOC Battle Command Training Program to address DOTMLPF issues.

Conclusion

Terrain understanding is a fundamental ingredient for success on the battlefield. Soldiers are increasingly using 3-D terrain visualization systems to show the "lay of the land," primarily using elevation data and imagery. The rapid advancement of computer technology and emerging terrain visualization technologies have made it possible for any soldier with a PC to achieve rapid terrain understanding. The Army uses standard systems provided through the acquisition cycle to meet the terrain visualization needs of field users. Field units are also acquiring nonstandard capabilities to augment standard systems and meet their immediate needs. The Army must address DOTMLPF and interoperability issues associated with these emerging capabilities in order to effectively manage the use of standard and nonstandard terrain visualization systems on the same battlefield.

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Correction: The January-March 2003 issue—which was labeled as Volume 32, PB 5-03-1—should have been Volume 33, PB 5-03-1.